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Memorandum

To: Regional Director, U.S. Fish and Wildlife Service
Pacific Southwest Region

From: Donald R. Glaser
Regional Director

Subject: Updated Adaptive Management Plan for the Implementation of Reasonable and Prudent Alternative Component 3 from 2008 Biological Opinion on the Long-Term Coordinated Operation of the Central Valley Project (CVP) and State Water Project (SWP)

On July 21, 2011, the Bureau of Reclamation transmitted to the Fish and Wildlife Service (Service) a memorandum describing planned CVP operations and expected SWP operations during the months of September, October and November 2011. The purpose of the planned operations is to satisfy the requirements of Component 3 of the Reasonable and Prudent Alternative (RPA), also referred to as the Fall X2 action, in the 2008 Biological Opinion on the effects of the Coordinated Long-Term Operation of the CVP and SWP on delta smelt and its designated critical habitat. The memorandum describes operations that will augment delta outflow during the months of September through November, with X2 (an index for the location of the low salinity zone) achieving an average value of 74 km in September and October, and outflow adjusted in November in response to actual runoff in November. The memorandum also committed Reclamation to provide an updated Adaptive Management Plan (AMP) for implementation of Component 3 to the Service in the near future. The purpose of this memorandum is to transmit the updated AMP to the Service.

Component 3 of the RPA expressly requires that the Fall X2 action be adaptively managed, to ensure that the implementation of the action addresses Fall X2 uncertainties about its effectiveness and water-efficiency. New scientific information developed during implementation may, as circumstances warrant, lead to changes to the Fall X2 action itself. The development of new scientific information entails studies of the physical and biological processes that are affected, or potentially affected, by the Fall X2 action. A 2010 draft AMP prepared by Reclamation, the Service, and scientific experts in the Delta proposed a program of studies addressing key topics, including hydrodynamic processes and sediment dynamics of the low-salinity zone (LSZ), nutrient dynamics, and effects and fate of ammonium in the LSZ.

The updated AMP provides a solid framework with which to move forward, and we believe it satisfies the intent of RPA Component 3. We also believe that the AMP should be viewed as a "living document" that will continue to evolve as adaptive management proceeds. We expect significant additional modifications to the plan in August as 2011 implementation discussions proceed, and additional evolutionary changes during the winter as the first year's data are analyzed and the parallel quantitative modeling effort moves forward. We generally expect that the first annual review will occur in June 2012, and expect discussions during the coming fall months will establish agency and stakeholder roles in that review. This version of the AMP represents a milestone in an ongoing cooperative process involving Reclamation, the Service, and others.

Reclamation expects that because of the broad agency interest in this AMP and its complexity, the implementation of the scientific studies and monitoring associated with the AMP will be managed by the IEP. The IEP has established expertise in long-term Delta ecosystem monitoring and investigation, including the Pelagic Organism Decline studies. The IEP also provides a means of assuring that the implementation of the AMP can be effectively managed by agency policymakers.

Reclamation appreciates the work of Service staff to implement the Fall X2 action this year, and looks forward to continuing the good working relationship in the future.

Attachment: Adaptive Management of Fall Outflow for Delta Smelt Protection and Water Supply Reliability

(4) SET-UP ELEMENT: MODELS ABOUT SYSTEM DYNAMICS AND DELTA SMELT RESPONSES TO FALL OUTFLOW MANAGEMENT

This plan relies on a Bay-Delta pelagic fishes conceptual framework developed by the IEP that identifies and interrelates fish abundance and key drivers that help to explain the pelagic organism decline (POD) (Sommer et al. 2007, Baxter et al. 2010). It also uses the subsequent adaptation of the POD conceptual models described in the 2010 HSG Adaptive Management Plan (USFWS 2010) as well as an ecosystem-based view of estuarine habitats that was presented by an expert group to the SWRCB in their proceedings to develop flow recommendations and which was reflected in the SWRCB's final report (SWRCB 2010). In the following sections we first briefly review the existing conceptual models and then provide a new conceptual model specifically designed for adaptive management of fall outflows in 2011. Results from monitoring and studies in 2011 will inform conceptual model refinement for future years.

a) Role of Quantitative Models

Numerical models quantifying and integrating many aspects of the conceptual models are currently under development (see monitoring and study plan section, and Appendix 2) and are expected to deliver results that will help guide fall outflow management in the coming years. Results from these models will, however, not be available for some time, and fall flow management in 2011 along with associated studies and monitoring will thus necessarily rely to a large degree on conceptual models. Development of quantitative models, and their integration with the Newman et al. life cycle model currently under development, will proceed on a parallel track with an expectation that one to several years will be required before products of sufficient quality and management applicability are available for use. The quantitative modeling framework included with a previous draft of this plan is provided as Appendix 2.

b) Existing Conceptual Models

Basic POD model - The basic POD conceptual model (Figure 10) focuses on the four POD fish species and is rooted in classical food web and fisheries ecology. It contains four major components: (1) prior fish abundance, in which abundance history affects current recruitment (i.e., stock-recruitment effects); (2) habitat, in which the amount of water (volume or surface area) with suitable conditions for a species has

This treatment recognizes that habitat features may affect each of the other categories of drivers additively, antagonistically, or synergistically, producing outcomes that are not always easily predictable.

Delta smelt species model - We also rely on the delta smelt species model developed by the POD investigators which focuses on delta smelt (Figure 11; Baxter et al. 2010).

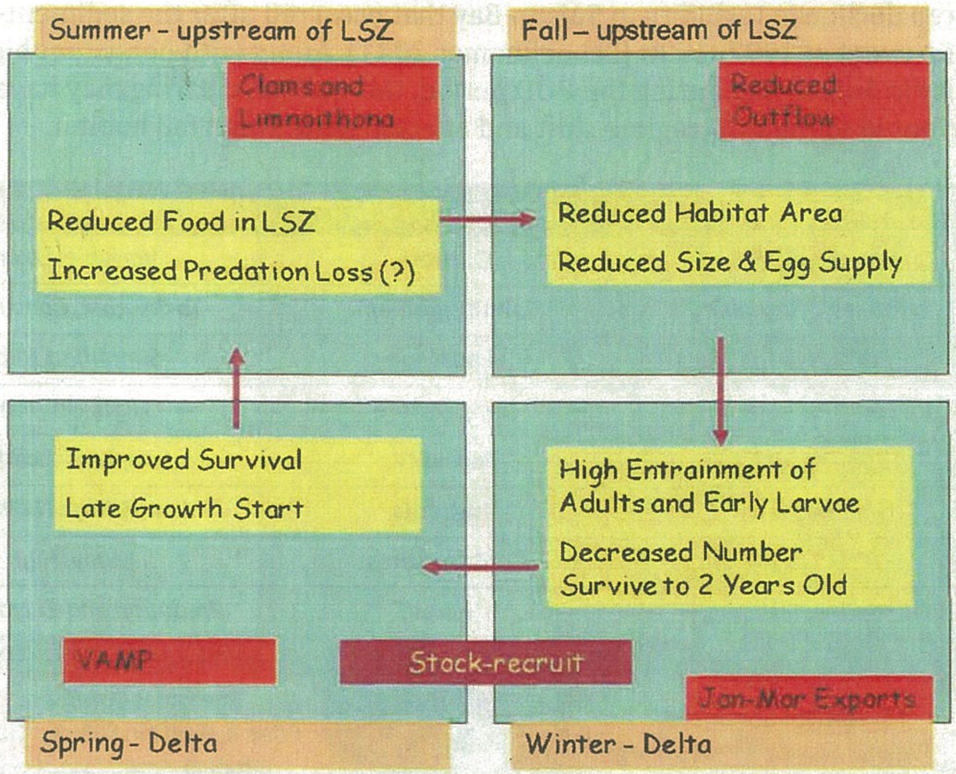


Figure 11. Delta smelt species model. Adapted from Baxter et al. 2010.

The model identifies key seasonal drivers in red, with proximal causes and effects in yellow. In fall, reduced habitat area is posited to affect the population through reduced growth and restricted egg supply rather than direct mortality. Fall effects therefore manifest themselves in potential limits on subsequent abundance, with the outcome depending on a variety of other seasonal factors.

Regime Shift Model – This more recently developed conceptual model focuses on the ecosystem of the upper estuary and posits that the POD is a manifestation of a rapid and comprehensive ecological regime shift that followed a longer-term erosion of ecological resilience in the estuary (Figure 12, see also Manly and Chotkowski 2006, Moyle and Bennett 2008, Baxter et al. 2010, Mac Nally et al. 2010, Thomson et al. 2010, the fall. This model represents habitat, bottom-up, and top-down drivers affecting delta smelt abundance, distribution, and health (Figure 13). Fall X2 is envisioned as a "filter" modifying the drivers and subsequent delta smelt responses. It implies that most of the potential effects of fall outflow are expected to occur through the processes that affect the growth and survival of juvenile and fecundity of adult delta smelt.

Figure 13. HSG model of effects of fall outflow on delta smelt through changes in habitat quantity and quality. Fall outflow affects (either directly or indirectly) the quantities on the left.

Estuarine Habitats Model - Peterson (2003) proposed an ecosystem-based view of estuarine habitats. A modified version of this view was presented by the Environmental Flows Group to the SWRCB in their recent proceedings to develop flow recommendations for the Delta. This group included regional technical experts including several members of the IEP POD team and others. Their view of estuarine habitats was reflected in the SWRCB's final report (SWRCB 2010) and provides the final piece for a new conceptual model for fall outflow adaptive management. In this view, the environment of an estuary consists of two integral parts:

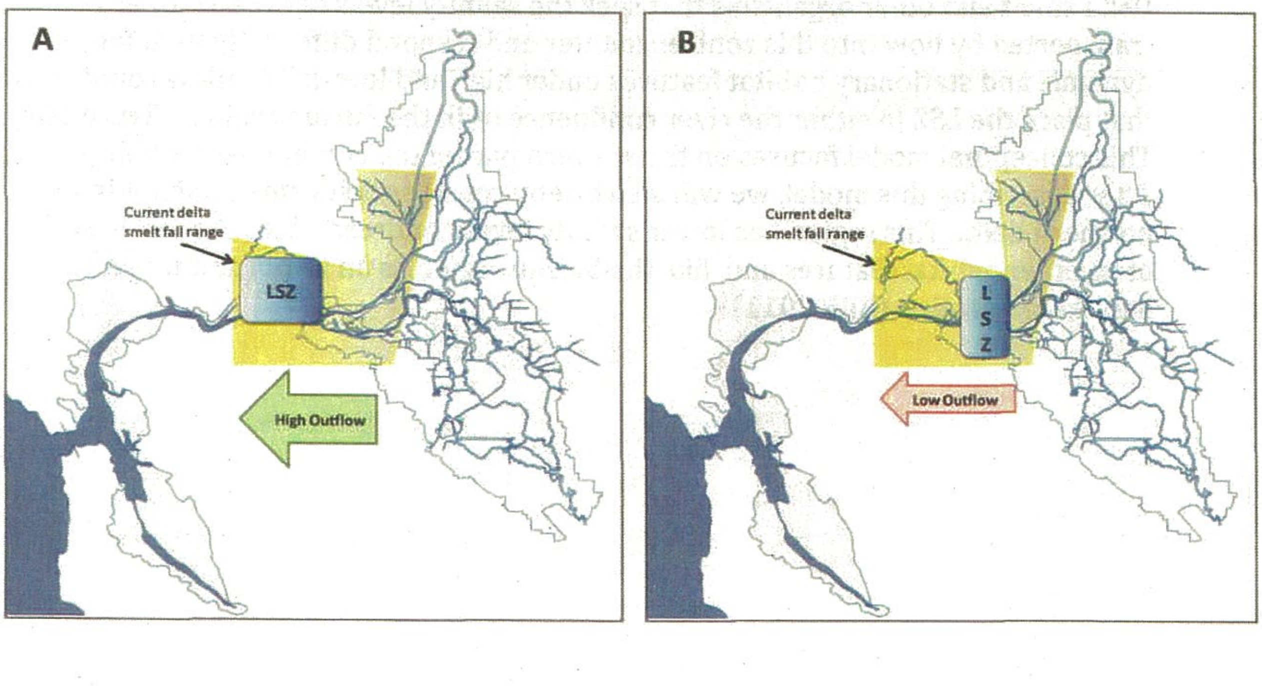
(1) a stationary topography with distinct physical features that produce different levels of support and stress for organisms in the estuary, and

turnover of resources, making the resources available to a shifting array of species. The variability implies that different processes interact at various scales in space and time, with the result that more species are present than would be characteristic of a hypothetical stable landscape (e.g., an agricultural landscape). Therefore, ecological theory strongly supports the idea that an estuarine landscape that is heterogeneous in salinity and geometry (depth, the configuration of flooded islands, tidal sloughs, floodplains, etc.) is most likely to have high overall productivity, high species richness, and high abundances of desired species." (Moyle et al. 2010).

c) A New, Spatially Explicit Conceptual Model For 2011

This new conceptual model combines and highlights aspects of the existing models pertaining to the effects of fall outflow management on delta smelt. It offers a way to describe and explore in more detail what is known and what remains uncertain about abiotic and biotic components of delta smelt fall habitat under different outflow scenarios. In this conceptual model, we distinguish between interacting dynamic and stationary (geographically fixed) abiotic habitat components that affect delta smelt, their predators, and their food resources in the river channels of the western Delta and in the Suisun region in the fall.

The dynamic habitat components are associated with different fall outflow regimes, while the stationary habitat components are associated with the specific physical structure of the low salinity zone when it is located in the confluence region of the Sacramento and San Joaquin Rivers (hereafter referred to as the "river confluence") or in the Suisun region. The Suisun region borders the river confluence to the west and includes Suisun Bay, Grizzly Bay, Honker Bay, and Suisun Marsh.



Suisun Region	Stationary Abiotic Habitat Components	*River Confluence*
Higher	Bathymetric Complexity	*Lower*
Higher	Erodible Sediment Supply	*Lower*
Many in South, Fewer in North	Contaminant Sources	*Many*
Fewer	Entrainment Sites	*More*
Variable Fall Outflow Regime	**Dynamic Abiotic Habitat Components**	***Static Fall Outflow Regime***
Higher After Wet Springs	Net Total Delta Fall Outflow	*Always Low*
Higher After Wet Springs	San Joaquin River Contribution to Fall Outflow	*Always Low*
After Wet Springs, Broad Fall LSZ Overlaps Suisun Region	Location and Extent of the Fall LSZ (1-6 psu)	***Narrow Fall LSZ In River Channels, Never Overlaps Suisun Region***
Higher After Wet Springs	Hydrodynamic Complexity in the Fall LSZ	*Always Lower*
Higher After Wet Springs	Wind speed in the Fall LSZ	*Always Lower*
More Variable, Higher After Wet Springs	Turbidity in the Fall LSZ	*Always Less Variable, Lower*
More Variable, Maybe Lower After Wet Springs	Contaminant Concentrations in the Fall LSZ	*Less Variable, Maybe Higher*
LSZ Overlaps Suisun Region	**Dynamic Biotic Habitat Components**	***LSZ Overlaps River Confluence***
Higher	Food Availability and Quality	*Lower*
Variable	Predator Abundance	*Higher*
LSZ Overlaps Suisun Region	**Delta Smelt Responses**	***LSZ Overlaps River Confluence***
Broad, Westward	Distribution	*Constricted, Eastward*
Higher	Growth, Survival, Fecundity	*Lower*
Better	Health and Condition	*Worse*
May be Higher	Recruitment in the next Spring	*Lower*

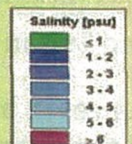


Figure 16. Spatially explicit conceptual model for the western reach of the modern delta smelt range in the fall: interacting stationary and dynamic habitat features drive delta smelt responses.

Here, we are primarily concerned with delta smelt responses to the fall X2 flow manipulation described in the OCAP Biological Opinion and the opportunities for learning offered by the very favorable hydrology of 2011, but this conceptual model can also be used to explore effects of dynamic and stationary drivers on other species and to inform and refine the other conceptual models summarized above. Further, by applying this model to the San Francisco Estuary and in particular to the dynamics of the low salinity zone and delta smelt responses in its entire fall habitat including the northern Delta, we capture the effects of all likely drivers not only on delta smelt, but on much of the ecosystem as a whole. This will contribute not only to a refinement of the delta smelt species model, but also to a better understanding of the ecological "regime shift" conceptualized by Baxter et al. (2010).

Stationary abiotic habitat components: The POD and HSG models suggest four key stationary habitat components that differ between the river confluence and Suisun regions and may affect habitat quality and availability for delta smelt. Each of the have resulted in pollution of the estuary with many chemical contaminants. Many of these pollutants (e.g. heavy metals, pesticides, etc.) are toxic to aquatic organisms and degrade the habitats of the estuary. Urban and industrial contaminant sources are located in the urban zones that surround the Delta and Suisun regions on all sides (Stoms 2010). Most wastewater treatment plants in and upstream of the Delta and Suisun regions have been upgraded to tertiary treatment which removes most inorganic nutrients and pathogens in addition to organic materials and also eliminates many pesticides and endocrine disrupting chemicals. However, the largest wastewater treatment plant in the Delta, the Sacramento Regional Wastewater Treatment Plant (SRWTP), continues to discharge effluent with high amounts of ammonium, pyrethroid pesticides, and other pollutants into the Sacramento River near the northern Delta border. The large Contra Costa wastewater treatment plant also discharges substantial amounts of ammonium and other pollutants into the western Suisun Bay near Carquinez Straight. Ammonium is converted to un-ionized ammonia at higher pH levels; un-ionized ammonia is toxic to animals. Ammonium has been found to suppress nitrate uptake and growth of phytoplankton in the Delta and Suisun Bay (Dugdale et al. 2007). In addition to man-made chemical pollution, blooms of the toxic cyanobacteria *Microcystis aeruginosa* have become a common summer occurrence in the central and southern parts of the Delta, including the river confluence and the eastern edge of the Suisun region. *Microcystis* produces chemicals that are toxic to many animals.

- *Entrainment sites:* Entrainment sites include agricultural water diversions and urban water intakes throughout the Delta and Suisun regions of the estuary, the state and federal water project pumps near Tracy, and two power plant cooling water intakes in the southern Suisun region (in Pittsburg and Antioch). Entrainment can cause direct mortality in fish screens, pumps, or pipes, or it can cause indirect mortality due to enhanced predation or unsuitable water quality associated with diversion structures and operations. Direct entrainment of delta smelt in the fall months is likely rare, although studies of entrainment effects of the power plants are ongoing. The plants are used mainly to satisfy peak electricity demands in the summer and fall months and could thus entrain delta smelt from the Suisun region, but the plants are not used very often and one of the plants will soon no longer use cooling water from Suisun Bay.

The starting distribution of delta smelt before winter migration is strongly influenced by salinity (Sommer et al. 2011). The winter spawning migration, which begins at the starting distribution and proceeds to points upstream, is typically initiated by "first flush" turbid river flows (Grimaldo et al. 2009; Sommer et al. 2011). A more eastward starting location may increase the risk of entrainment at the State and Federal water projects when "first flush" under unimpaired conditions without reservoirs, flow diversions, and groundwater pumping. In general, late fall, winter, and spring inflows into the Delta are lower than under unimpaired conditions, while summer and early fall inflows are higher (Moyle et al. 2010). On an annual basis, San Joaquin River flows are reduced to a much greater extent than Sacramento River flows, and only a small amount of San Joaquin River water is actually discharged to the ocean in all but the wettest years. This is especially true in the fall months, when only a very small fraction of the entire water volume at Chipps Island is contributed by water from the San Joaquin River. According to hydrodynamic modeling using the Delta Simulation Model 2 (DSM2, see http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm), water from the Sacramento River and water intruding from San Francisco Bay via Carquinez Straight are by far the dominant water sources during these months and throughout most of the year (Figure 17). Even with greater wet year fall outflows, the San Joaquin River contribution to total outflow will likely remain small.

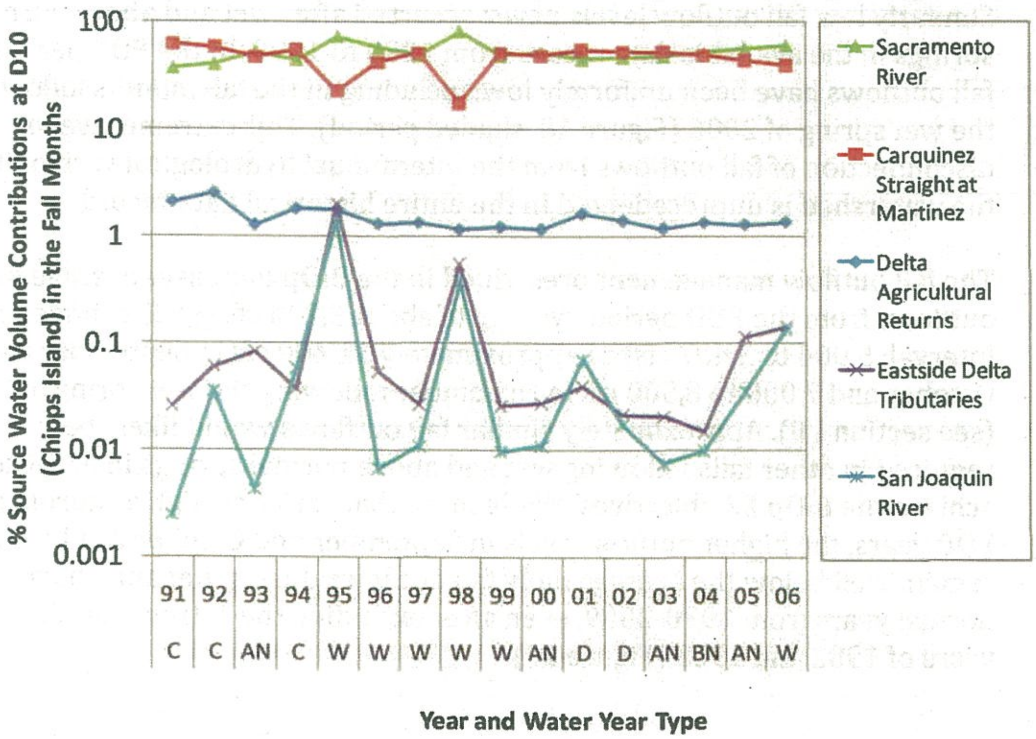


Figure 17. 1995-2006 times series of average seasonal water contributions from different sources to the total water volume at IEP-EMP station D10 at Chipps Island. Data: Volumetric water source "fingerprint" data for this station generated with the Delta Simulation Model 2 (DSM2, http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.c

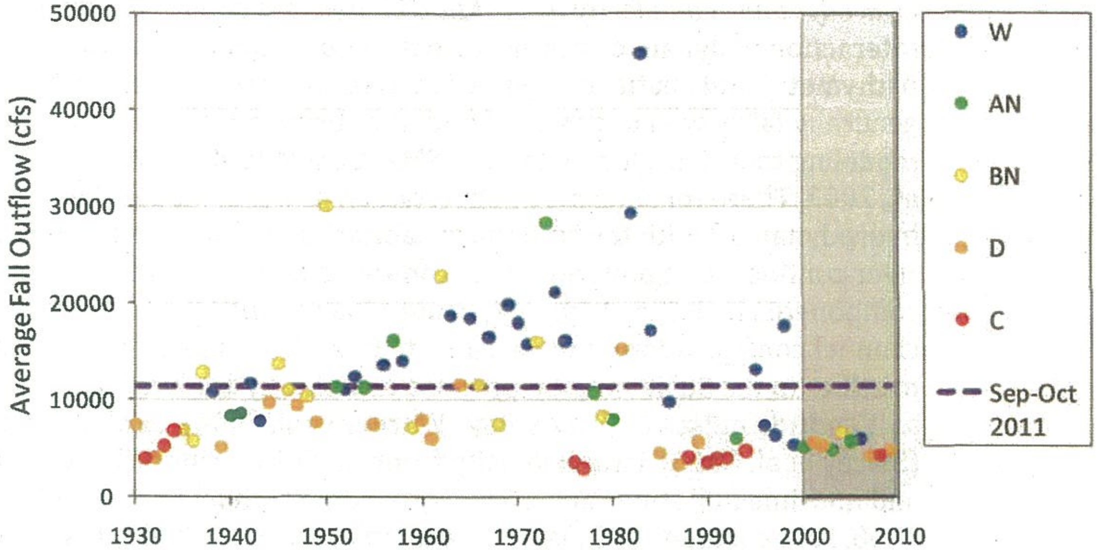


Figure 18. Time series of average daily net Delta outflow index in the fall (cfs, September – November) from 1930 to 2009. The shaded area shows the POD period. Symbols: water year type of the preceding spring for the Sacramento valley (W: wet, AN: above normal, BN: below normal, D: Dry, C: critically dry). Dashed purple line: projected average daily net Delta outflow level for September and October 2011. (Data source: Dayflow (http://www.water.ca.gov/dayflow/). Graphic: A. Mueller-Solger, unpublished.)

- *Location and extent of the fall LSZ:* Under the static fall outflow regime that has been typical for the POD period, outflows throughout much of the fall are always low and salinity intrudes far to the east (X2>80km, Figure XX, see also Figure 7), causing the LSZ to be constricted into a narrow band that overlaps the confluence of the deep Sacramento and San Joaquin river channels (Figure 6b). Prior to the POD period, a more variable fall outflow regime meant that high outflows in the spring were often followed by relatively high outflows in the fall of the same year (Figure 7 and Figure XX). Higher fall freshwater outflows do not allow salinity from the ocean to intrude into the river confluence. Instead, the LSZ is more westward (X2<80km) and much more spatially extensive than in low outflow falls (Figure 6a). In high outflow falls, it broadly overlaps the large shallow embayments of Suisun, Honker, and Grizzly Bays and reaches substantially into Suisun Marsh sloughs and wetlands. On an annual basis, the difference between X2 calculated for actual and unimpaired flows increased by 1.4% per year from 1932 to 2009 due to water management that resulted in a decline in outflow and allowed increasingly more salinity intrusion. The difference has been especially pronounced during the post-1960 droughts, with substantially greater salinity intrusions than the estuary experienced historically, including during the Dust Bowl drought of the 1930s (Winder et al. 2011).

- Turbidity in the fall LSZ: In the San Francisco Estuary, turbidity is largely determined by the amount of suspended inorganic sediments in the water (Cloern 1987, Ganju et al. 2007, Schoellhamer et al. in press), although organic components likely also play an important role (USGS 2008). Sediment particles are constantly deposited, eroded, and resuspended, and are transported into, within, and out of the estuary. The amount of sediment that is suspended in the water column depends on the available hydrodynamic energy, which determines transport capacity, and on the supply of erodible sediment. In the late 1800s, enormous amounts of sediments were washed into the rivers in the estuary's watershed by hydraulic gold mining. A substantial portion of these sediments was deposited in the rivers and bays of the estuary because the transport capacity was not enough to wash them out to the ocean. In the 1900s, river-borne sediment supplies started to decline due to the end of hydraulic mining, sediment trapping behind newly constructed dams, and rip-rapping of river banks for flood protection. This meant that the eroding sediment pool was no longer rapidly replenished from upstream and started to wash out to the ocean, leaving behind thinning bed sediments and slowly declining turbidity levels. High flushing flows associated with two recent, strong El Niño-Southern Oscillation (ENSO) events led to the sudden and permanent clearing of the river confluence in 1983 (Jassby et al 2005) and the bays of the San Francisco estuary in 1999 (Schoellhamer 2011). In the western estuary, the onset of this clearing coincided with the onset of the POD period. It appears that turbidity from suspended sediments is now regulated by the bed supply of sediments, not by the transport capacity of the estuary, a situation that was not experienced in the estuary since before the gold rush.

  In spite of the depletion in erodible sediments, strong turbulent hydrodynamics in the Suisun region that are caused by strongly interacting tidal and riverine flows, bathymetric complexity, and high wind speeds continue to constantly resuspend large amounts of the remaining erodible sediments in the large and open shallow bays of the Suisun region. The Suisun region thus remains one of the most turbid regions of the estuary. Turbidity dynamics in the deep channels of the river confluence are driven more by riverine and tidal processes while high wind and associated sediment resuspension has little if any effect (Ruhl and Schoellhamer 2004). In Fall, fine erodible sediment has been somewhat winnowed from the bed and wind speed is less than spring and summer, so wind wave resuspension and suspended-sediment concentrations typically are low compared to other seasons. While generally lower than in the last century, turbidity in the river confluence can still increase dramatically during high flow events ("first flush") that bring in large amounts of suspended sediments from the watershed. In the fall, however, turbidity is usually lower in the river confluence than in the Suisun region (Bennett and Burau 2011). This is also consistent with preliminary analyses by W. Kimmerer (SFSU, pers. com.) that regulated sediment transport regime does not allow for much contaminant burial in bed sediment. Overall, this may increase the risk of exposure to toxic contaminants in the river confluence compared to the Suisun region. On the other hand, the southern margin of the Suisun region is heavily urbanized and includes the Contra Costa wastewater treatment plant which discharges ammonium and other pollutants into the western Suisun Bay near Carquinez Straight. Ammonium is converted into nitrate as it moves downstream, but elevated levels are often found in both the river confluence and the Suisun region. Higher phytoplankton productivity in the Suisun region may drive up pH levels, which could lead to increased levels of toxic un-ionized ammonia. Higher benthic productivity and resuspension of sediments in the shallow areas of the Suisun region can mobilize sediment-bound contaminants and introduce and accumulate them in the food chain. Suisun Marsh is bordered by a large urban area along its northern margin and much of its wetlands are managed by duck clubs. Urban areas and duck clubs are known to pollute Marsh sloughs with chemical contaimants and high loads of organic matter. Contaminant exposure risk may thus be overall more variable and not always lower in the Suisun region than in the river confluence.

Dynamic Biotic Habitat Components: Estuarine fishes seek areas with a combination of dynamic and stationary habitat components that are well suited to their particular life histories. In addition to abiotic habitat components, this also includes dynamic biological components such as food availability and quality and composition and predator abundance and composition.

- *Food availability and quality:* Food production in estuaries is a dynamic process that involves the entire food web, from algae, microbes, and aquatic plants at the base of the food web to intermediate and higher trophic levels populated by invertebrates such as zooplankton and benthic consumers and vertebrates such as fishes and water birds. As in many other estuaries, higher trophic level production in the open waters of the Delta and Suisun regions is fueled by phytoplankton production (Sobczak et al. 2002). In contrast to many other estuaries, however, the San Francisco estuary has overall low phytoplankton production and biomass (Cloern and Jassby 2008). Phytoplankton production in the estuary is highly variable on a seasonal and interannual basis (Jassby et al. 2002, Cloern and Jassby 2009). The San Francisco estuary also has a large amount of spatial variability in food production and food web dynamics. Estuaries and rivers often have dynamic food and biogeochemical "hot spots" (Winemiller et al. 2010) that persist in one location for some time or move with river and tidal flows. There are usually also areas with low food production and biomass.

  Not all highly productive hot spots are beneficial for consumers. For example, summer-time blooms of the cyanobacteria *Microcystis aeruginosa* that now

Estuaries are open systems and food inputs from rivers and the ocean are an important driver of food web dynamics in estuaries. Of the two main tributary rivers to the San Francisco estuary, the San Joaquin River has generally more phytoplankton and zooplankton production and biomass than the Sacramento River. San Joaquin River waters along with the plankton they contain rarely reach the LSZ under low outflow conditions in the fall because the San Joaquin River is largely diverted into the water projects under these conditions. Higher outflow conditions and altered water management may allow some of the San Joaquin River biomass loads to reach the Suisun region in falls following wet springs, thus subsidizing the food available to delta smelt in the LSZ. Food production and biomass is also known to be high in some of the sloughs in Suisun Marsh (Sobczak et al 2002, Mueller-Solger et al 2002). When the LSZ extends into these sloughs, delta smelt may benefit from the production directly in some of the more open sloughs. If Suisun Marsh is a source of plankton organisms for Suisun bay, delta smelt may also benefit from Suisun Marsh food subsidies to the Suisun Bay, however the role of Suisun Marsh as a food source or sink remains uncertain. The river confluence likely receives substantial amounts of riverine organic matter from upstream, but much of this organic matter is not very nutritious and supports less higher trophic level production than autochthonous phytoplankton and fresh wetland production (Mueller-Solger et al. 2002, Sobzack et al. 2002). On the other hand, large amounts of detrital organic matter transported into and produced in the system are utilized by heterotrophic microbes (bacteria and protists) and microbial production and respiration in the system is high (Sobczak et al. 2002). Microbial biomass in the LSZ appears to nutritionally benefit at least one zooplankton species in the LSZ, the invasive cyclopoid copepod *Limnoithona tetraspina* (Bouley and Kimmerer 2006). However, in spite of its high abundance in the LSZ, this copepod species is not a good food source for juvenile and sub-adult delta smelt due to its small size (Sullivan et al. 2010). In the LSZ, microbes are often so heavily grazed by the invasive clam *Corbula amurensis* that their biomass can only be maintained through subsidies from other regions less affected by the clams (Greene et al 2011).

The overbite clam *Corbula amurensis* invaded the Suisun and river confluence regions in the late 1980s. This invasion led to a dramatic decline in the productivity in and upstream of these regions (Jassby et al. 2002). However, *Corbula* recruitment is suppressed and densities are lower in years with higher outflows and a more westward LSZ and X2 (Peterson and Vayssieres 2010, Winder et al. 2011), such as the wet 2011 – preliminary IEP monitoring results from this spring and early summer show very low numbers of live *Corbula* in the Suisun region. Without high densities of large *Corbula* in the fall, the Suisun region may have higher phytoplankton biomass this fall than in years with more *Corbula* which, along with reduced *Corbula* predation on juvenile zooplankton, would benefit zooplankton production.

is in Suisun Bay than if it is in the river confluence, but many uncertainties remain.

- *Predator composition and abundance*: Predators are a natural biological component of ecosystems and most organisms are exposed to predation during some part of their lives. In general, a reduction in habitat size may increase the probability of predation in that habitat. Even for a rare species like delta smelt, reduced habitat availability may increase the probability of a stochastic event such as an encounter between the core population of delta smelt and a school of predators. In the San Francisco estuary, striped bass juveniles become piscivorous and occupy much the same areas as delta smelt in the fall. Predation on delta smelt by young striped bass may be enhanced in recent years by a general increase in size of striped bass young of year and the general decrease in size of juvenile delta smelt, although the abundance of juvenile striped bass has decreased in the open waters of the estuary (Thomson et al. 2010). Striped bass occur in both the confluence and the Suisun region. Higher turbidity in the shallow areas of the Suisun region may, however, reduce predation risk for delta smelt in these areas compared to the river confluence, where turbidity is generally lower. In addition, preliminary results indicate that open-canopied beds of the native submerged aquatic vegetation (SAV) *Stuckenia pectinata* (sago pondweed) may provide cover from predation, although this has not yet been observed for delta smelt (K. Boyer, SFSU, pers. com.). This relatively salt-tolerant SAV species currently occurs in shallow off-shore areas extending from the western margin of the river confluence west into Grizzly Bay (K. Boyer, SFSU, pers. com.). In the fresher, warmer and clearer waters in and upstream of the river confluence, the dominant SAV species is the non-native *Egeria densa*. Its denser canopies provide ideal conditions for ambush predators such as largemouth bass (L. Conrad et al., DWR, pers. com.). Largemouth bass are increasingly abundant in the central and northern Delta and may potentially exert significant predation pressure on delta smelt in the river confluence and the clearer areas of the Suisun regions, although this has not yet been documented. Sacramento pikeminnow, a native predator, occurs in both regions. Mississippi silversides, another introduced species, appear to prey on larval delta smelt in the spring, but are likely too small to prey on juvenile and sub-adult delta smelt in the fall (B. Schreier, DWR, pers. com.). High predator abundance has been documented in the river confluence at the release sites for fishes salvaged in the CVP and SWP fish facilities. Overall, predator abundance and associated predation risk for delta smelt may be generally high in the river confluence, but variable in the Suisun region. Much uncertainty remains, however, about the role and magnitude of predation in these regions.

- *Health and condition:* Similar to the mechanisms listed for growth, survival and fecundity, a broader distribution across the bathymetrically complex Suisun region can affect health and condition. For example, more habitat may help delta smelt avoid, or reduce exposure to, toxic hot spots, limit entrainment to diversions and access better food resources, compensate for degraded physical habitat elsewhere.
- *Recruitment in the next spring:* Ultimately, the factors listed above may lead to greater recruitment of delta smelt. However, before they can recruit successfully, delta smelt need to find suitable spawning and larval rearing habitat upstream of the low salinity zone. In addition to summer and fall habitat conditions, successful recruitment thus requires suitable winter and spring conditions for migration, spawning, and larval rearing. These habitat conditions depend on the interplay of a different set of stationary and changing dynamic habitat features. Only if habitat conditions are met year-round will delta smelt be able to successfully maintain their life history and genetic diversity and thus, maintain a viable population in their original habitat into the future.

Delta Smelt In the Northern Delta: While the center of the delta smelt distribution in the fall is the low salinity zone, they also occur year-round in the northern Delta, but are no longer found in their historical range in the southern Delta in the summer and fall (Nobriga et al. 2008, Sommer et al. 2011). Because delta smelt are currently found in the northern Delta in the fall, this region also constitutes current delta smelt fall habitat. It is important to note, however, that habitat quality and resulting delta smelt survival, health, growth, fecundity and recruitment contribution to the total population may differ between this region and the low salinity region. The 2011 study plan includes a comparison of dynamic and stationary habitat features and delta smelt responses in the LSZ and northern Delta habitats.

The northern Delta range of delta smelt in the fall includes the Sacramento deepwater ship channel and the Cache Slough complex with its dead-end sloughs and the large, flooded Liberty Island. This region has a number of similarities in stationary habitat features with the Suisun region: compared to the mainstem Sacramento River, it is bathymetrically complex, turbid, productive, and has low entrainment risk and variable risk of toxin exposure and predation. Dynamic habitat features include strong tidal exchanges with the Sacramento River, variable contributions of highly productive tributary waters, and increasing salinity levels up to about 0.5 psu from the mainstem Sacramento River into the ship channel and the smaller sloughs. Like the Suisun region, the northern Delta region is also targeted for habitat restoration activities. Learning more about its habitat suitability for juvenile delta smelt in the summer and fall thus provides not only an informative comparison for the low salinity habitat investigation, but will likely also yield key insights for implementing more science-based habitat restoration in both areas.